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BACKGROUND AND MOTIVATION

- Logistics research often has a reverse synthesis function
- Assumption: fundamental principles underlie successful logistics applications based on robotic motion planning
- Informal axiomatic framework: less rigorous, more intuitive understanding of a domain
- What theoretical construct could serve as a unifying foundation to comprehensively promote a deeper understanding of logistics as a science?
- Goal: find all relevant axioms that are useful/relevant for the design of logistic systems



The Loadrunner as an example of free-form motion planning in a packet sorting application

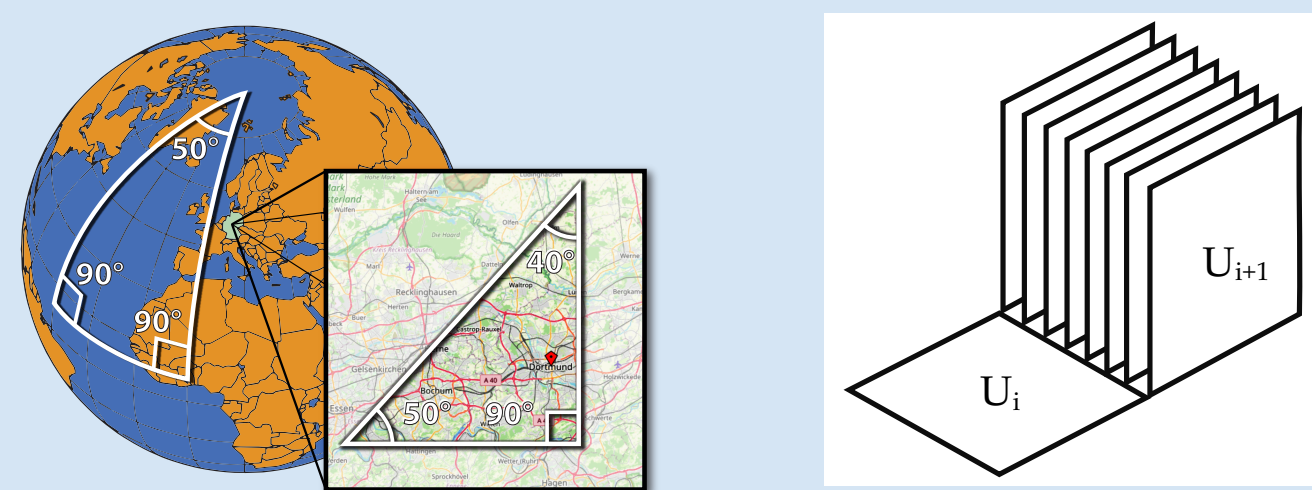


The AutoStore system as an example of grid-based motion planning in a bin storage application ©AutoStore

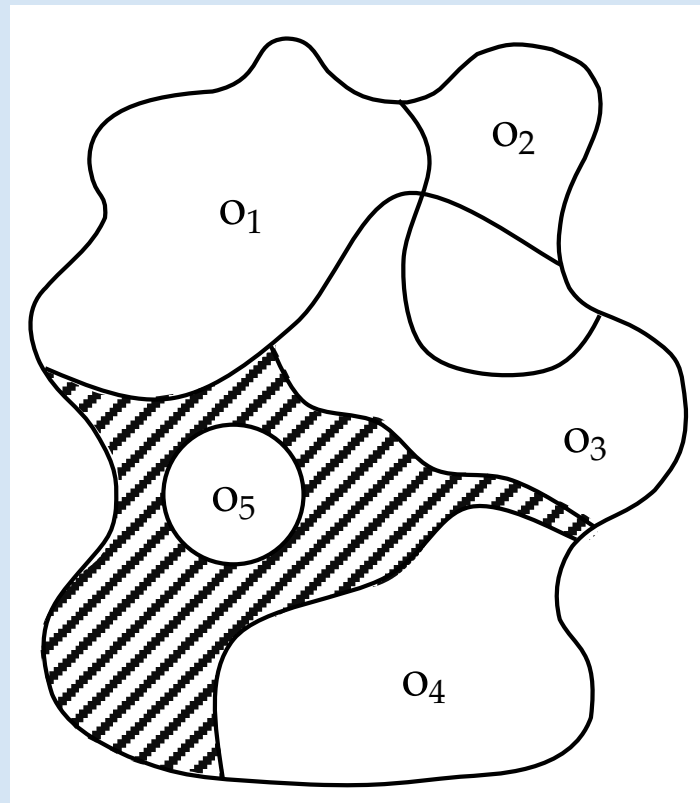
(a) A logistic axiom is an intuitively evident concept and empirically well-confirmed in practical working life. (b) Logistic axiomatic frameworks are generally evidence-based and need not be formally complete. (c) They provide a foundation for a meaningful reduction of reality upon which models can be built. (d) Their true value becomes apparent only in practical application.

STRUCTURING SPACE

- Logistics Space as a manifold
- Areas and Locations
- Material, Articles, Objects



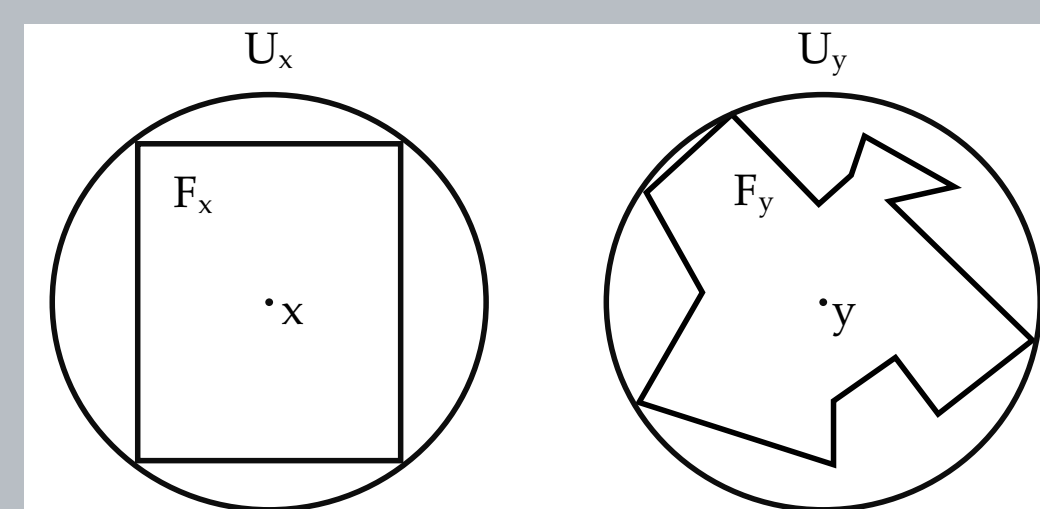
Earth and a high-bay warehouse as manifolds, i.e. atlases containing maps



Logistic Areas on a map within Logistic Space

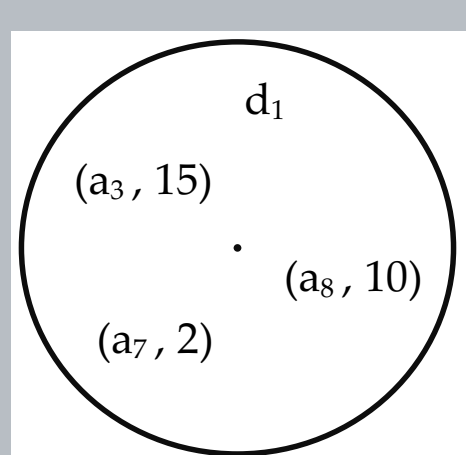
Axiom of Separation

Objects and Locations are separated.



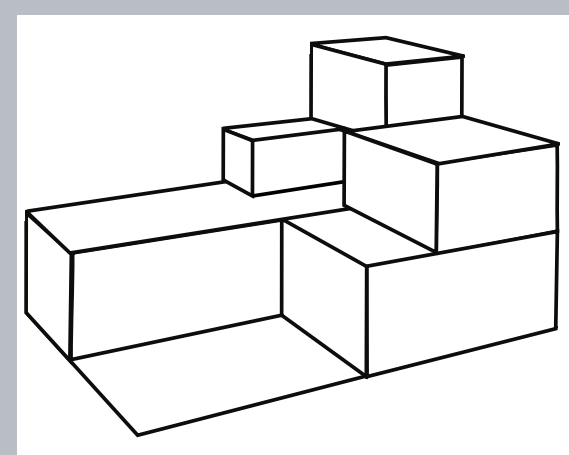
Axiom of Containing

Objects contain Material and Articles.



Axiom of Uniting

Objects unite under parent objects.

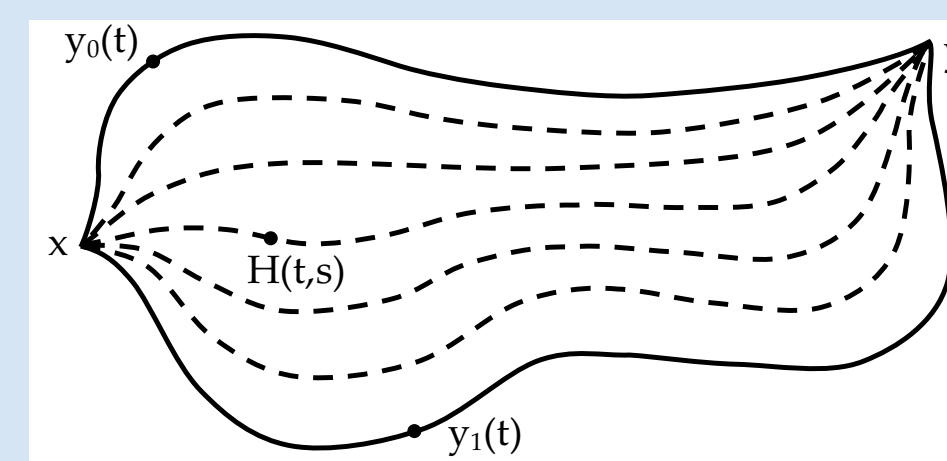


Axiom of Local State Change

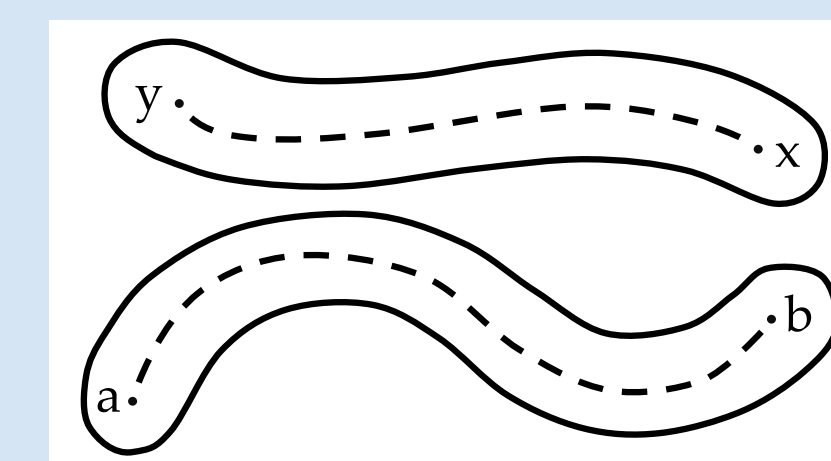
Two objects must be in each other's neighborhood in order to change their respective states relative to each other. Motion as a system-wide change in the location of an object occurs through a concatenation of local position changes.

MOTION PLANNING

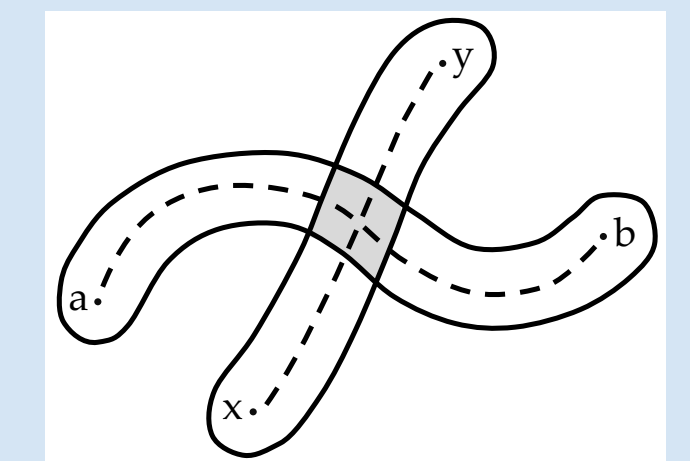
- Path: a physical possible movement trajectory of an object
- Relation: one or more paths exist permanently between locations/areas



Homotopy of two paths



Disjunct paths



Path with collision zone

Axiom of Non-collision

The movement of all logistic objects is collision-free. Two objects cannot be in the same place at the same time. The velocities of two objects on intersecting trajectories are always assumed to be adjusted in such a way as to avoid collisions.

Axiom of Recurring Movements

Logistics is characterized by recurring movements over relations. The planning of these movements requires the investigation of the possibility of parallel movement over all possible paths of all relations.

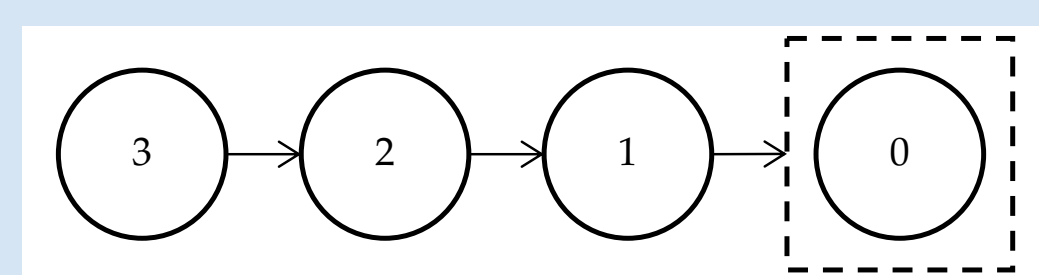
DEFINITION OF LOGISTICS

Logistics involves the *rational movement** of logistic objects within logistic space, through time, and in relations.

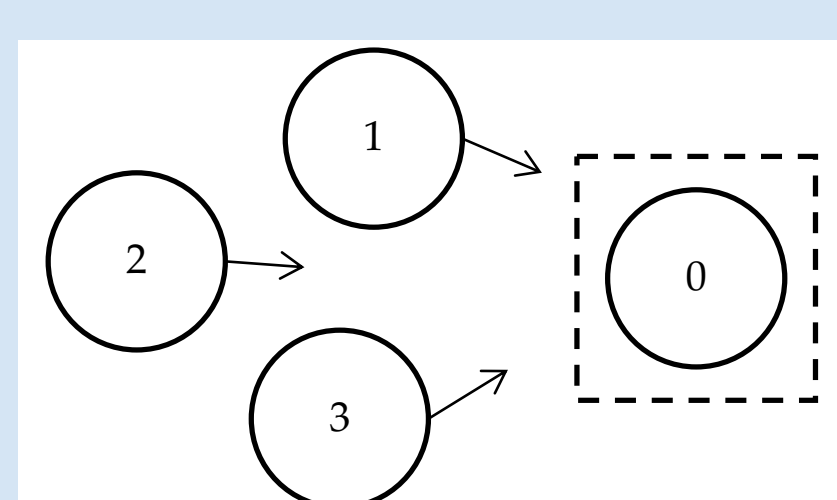
*The concept of rationality includes the principles of classical optimization (e.g., operations research)

PROCESSES AND QUEUES

- Processes: not explicitly defined
- Queues: sets of logistic objects that are interdependent by their before-after relationship until they have passed through a special location



Classic queue

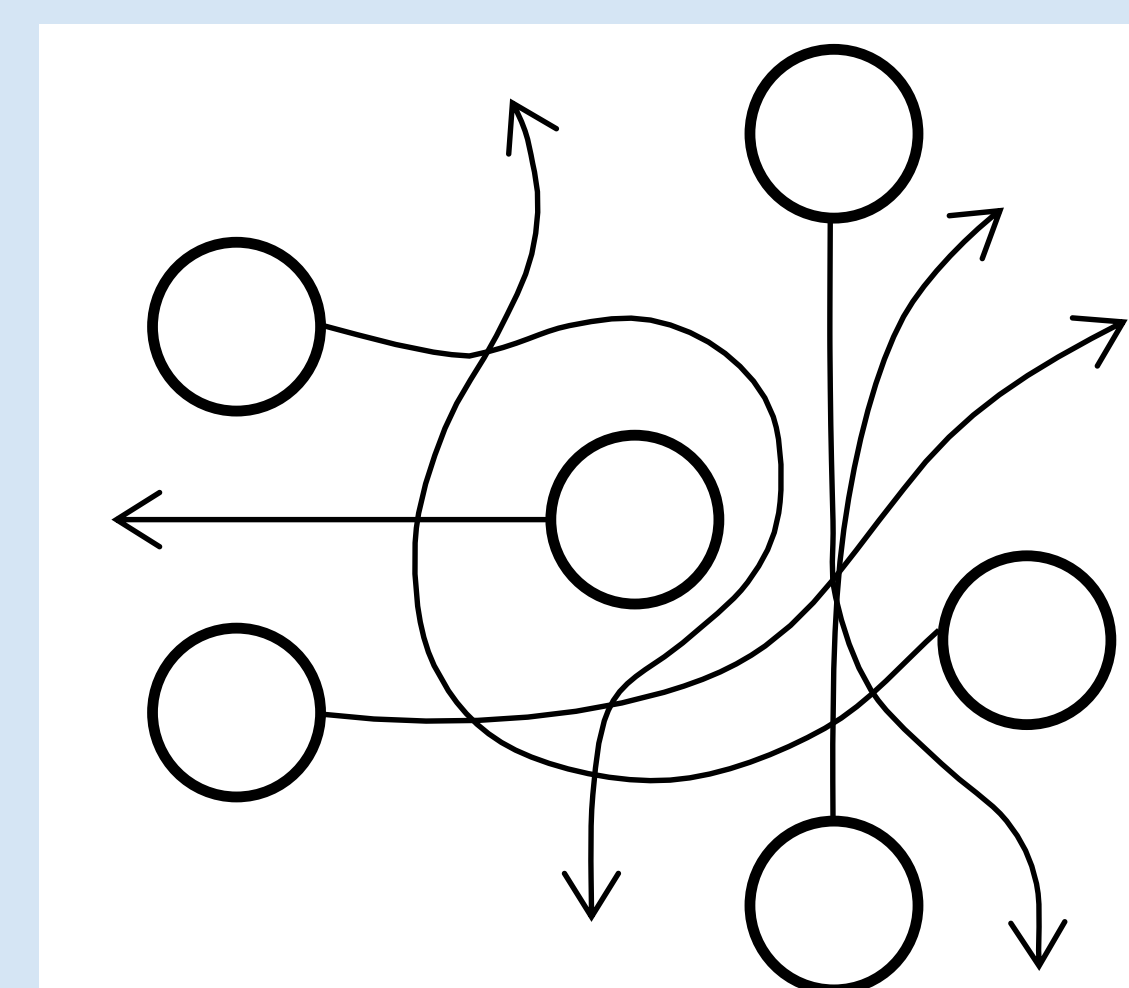


Distributed queue

Axiom of Special Areas and Locations

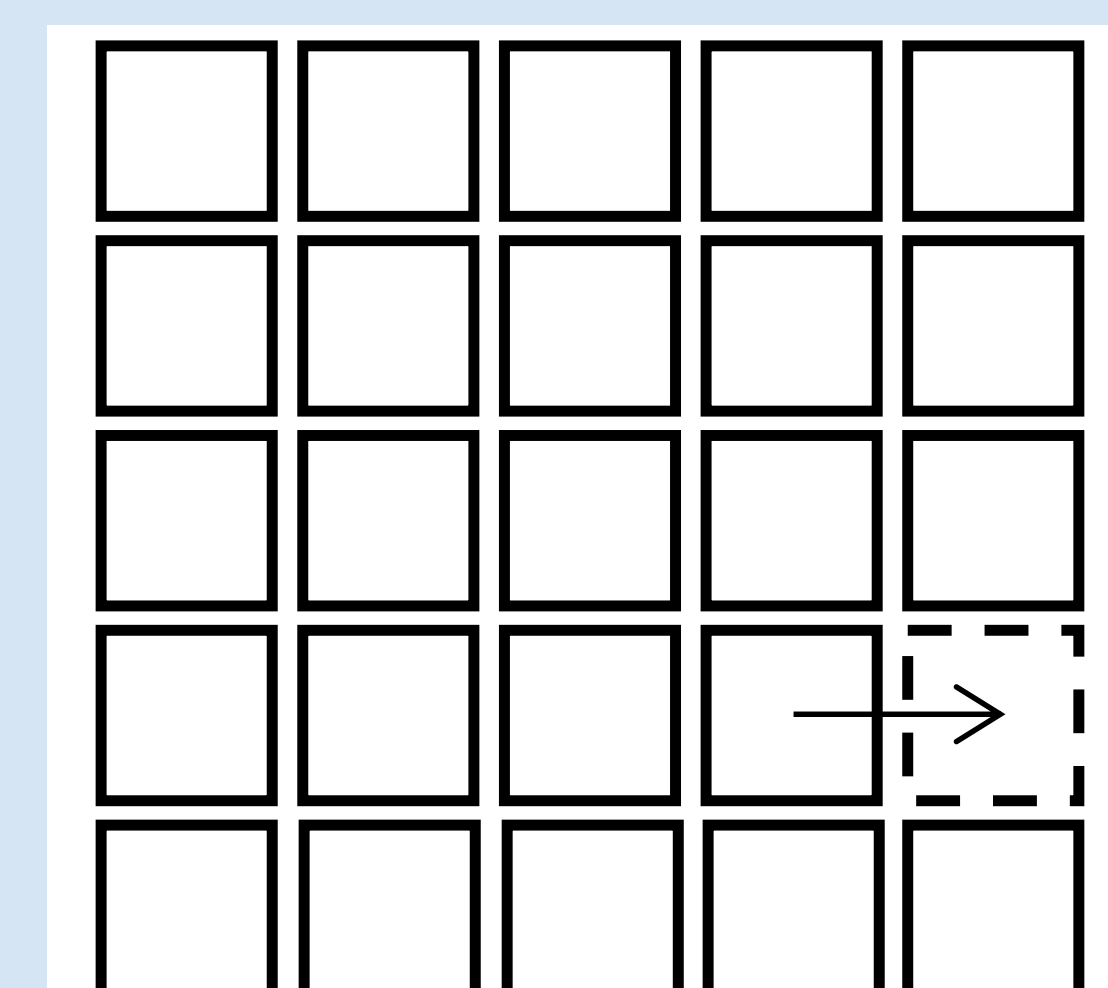
The logistic space contains special areas and locations. State changes are defined that can be performed at these areas and locations. They are the starting points and destinations of relations (i.e., sources and sinks).

IDEALIZED TRANSPORTATION AND STORAGE SYSTEMS



Idealized Transportation System

Simultaneous free-form and collision-free movement of all objects



Idealized Storage System

Sparse, collision-free movement with grid-based separation, most objects are in resting state